HIGHLIGHTS and CONCLUSIONS
of the Chalonge 13th Paris Cosmology Colloquium:
'The Standard Model of the Universe: From Inflation to Today Dark Energy',
Ecole Internationale d'Astrophysique Daniel Chalonge, Observatoire de Paris in the historic Perrault building, July 2009.

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(Dated: July 21, 2010)

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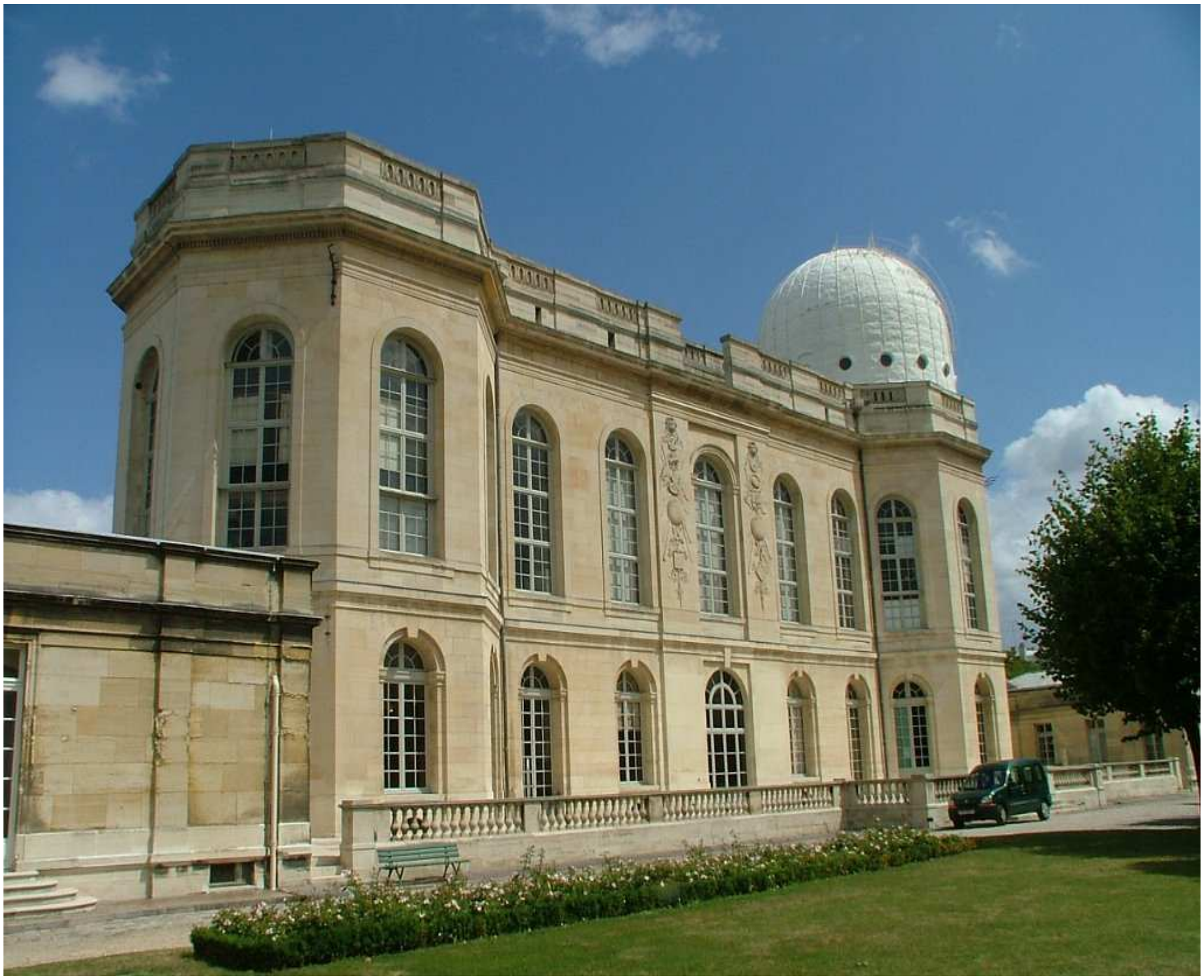


I. PURPOSE OF THE COLLOQUIUM AND INTRODUCTION

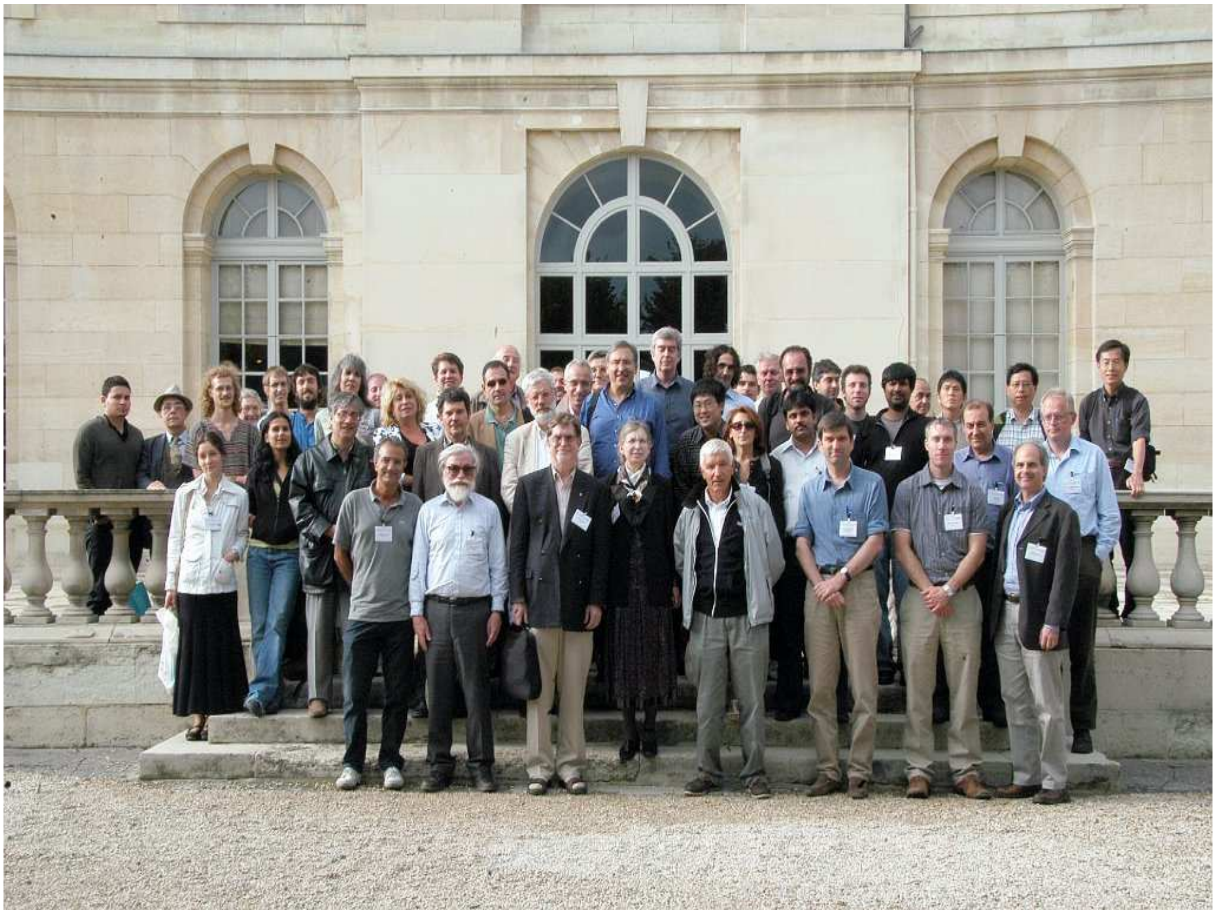
The main aim of the series "Paris Cosmology Colloquia", in the framework of the International School of Astrophysics **"Daniel Chalonge"**, is to put together real cosmological and astrophysical data and hard theory approach connected to them. The Paris Cosmology Colloquia bring together physicists, astrophysicists and astronomers from the world over. Each year these Colloquia are more attended and appreciated both by PhD students, post-docs and lecturers. The format of the Colloquia is intended to allow easy and fruitful mutual contacts and communication.

The subject of the 13th Paris Cosmology Colloquium 2009 was "THE STANDARD MODEL OF THE UNIVERSE: FROM INFLATION TO TODAY DARK ENERGY", George Smoot, Nobel Prize of Physics 2006 and Daniel Chalonge Medal .

The Colloquium took place during full three days (Thursday July 23, Friday 24 and Saturday July 25) at the parisian campus of Paris Observatory (HQ), in the historic Perrault building.

The **13th Paris Cosmology Colloquium 2009** was within the astrofundamental physics spirit of the Chalonge School, focalized on recent observational and theoretical progress on the CMB and inflation with predictive power, dark matter, dark energy, dark ages and LSS in the context of the Standard Model of the Universe. Never as in this period, the Golden Age of Cosmology, the major subjects of the Daniel Chalonge School were so timely and in full development: the WMAP mission released in April 2008 the new survey (5 years of observations) and the PLANCK mission has been launched (May 2009) and is performing its First Survey.

The **main topics** were: Observational and theoretical progress in deciphering the nature of dark matter, dark energy, dark ages and the 21 cm line. Large and small scale structure formation. Inflation after WMAP (in connection



with the CMB and LSS data), slow roll and fast roll inflation, quadrupole suppression and initial conditions; quantum effects. CMB polarization, primordial magnetic fields effects. Neutrinos in cosmology. Measurements of the CMB by the Planck mission and its science perspectives.

All Lectures are plenary and followed by a discussion. Enough time is provided to the discussions.

Informations of the Colloquium are available on

http://chalonge.obspm.fr/colloque2009.html

Informations on the previous Paris Cosmology Colloquia and on the Chalonge school events are available at

http://chalonge.obspm.fr

(lecturers, lists of participants, lecture files and photos during the Colloquia).

This Paris Colloquia series started in 1994 at the Observatoire de Paris. The series cover selected topics of high current interest in the interplay between cosmology and fundamental physics. The PARIS COSMOLOGY COLLOQUIA are informal meetings. Their purpose is an updated understanding, from a fundamental point of view, of the progress and current problems in the early universe, cosmic microwave background radiation, large scale structure and neutrinos in astrophysics and the interplay between them. Emphasis is given to the mutual impact of fundamental physics and cosmology, both at theoretical and experimental -or observational- levels.

Deep understanding, clarification, synthesis, a careful interdisciplinarity within a fundamental physics approach, are goals of this series of Colloquia.

Sessions last for three full days and leave enough time for private discussions and to enjoy the beautiful parisian campus of Observatoire de Paris (built on orders from Colbert and to plans by Claude Perrault from 1667 to 1672).

Sessions take place in the Cassini Hall, on the meridean of Paris, in "Salle du Conseil" (Council Room) in the historic Perrault building ("Btiment Perrault") of Observatoire de Paris HQ, under the portraits of Laplace, Le Verrier, Lalande, Arago, Delambre and Louis XIV and in the "Grande Galerie" (the Great Gallery).

An **Exhibition** retraced the 18 years of activity of the Chalonge School and of George Smoot participation to the School along these 18 years. The books and proceedings of the School since its creation, as well as historic Daniel Chalonge material, and Chalonge instruments were on exhibition at the Great Gallery.

During the Colloquium, the International School of Astrophysics "Daniel Chalonge" has awarded the **Daniel Chalonge Medal 2009** to **Prof. Peter Biermann** from MPI Institut of Radioastronomie of Bonn (D) and University of Alabama Tuscaloosa (USA) and for his outstanding support and contributions to the Chalonge School.

After the Colloquium, a tour of the Perrault building took place guided by Professor Suzanne Debarbat around the subject "From Hipparque to the Hipparcos satellite".

More information on the Colloquia of this series can be found in the Proceedings of the Colloquia from 1994 (H.J. de Vega and N. Snchez, Editors) published by World Scientific Co. and by Observatoire de Paris.

We want to express our grateful thanks to all the sponsors of the Colloquium, to all the lecturers for their excellent and polished presentations, to all the lecturers and participants for their active participation and their contribution to the outstanding discussions and lively atmosphere, to the assistants, secretaries and all collaborators of the Chalonge School, who made this event so harmonious, wonderful and successful .

With Compliments and kind regards,

Hector J de Vega, Maria Cristina Falvella, Norma G Sanchez

École Internationale Daniel Chalonge

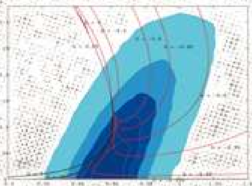
13th Paris Cosmology Colloquium 2009

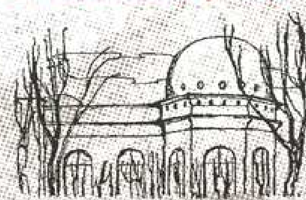
THE STANDARD MODEL OF THE UNIVERSE : FROM INFLATION TO TODAY DARK ENERGY

George Smoot, Nobel Prize of Physics and Daniel Chalonge Medal

OBSERVATOIRE DE PARIS, PARIS CAMPUS

Thursday **23**, Friday **24**, Saturday **25** July 2009





PROGRAMME and LECTURERS INCLUDE

- **Tom ABEL** (Stanford Univ., Physics Dept. CA. USA) First Galaxies and Cosmological Reionization.
- **Nicola BARTOLO** (INFN Univ Padova, Italy) Primordial Non-Gaussianity and the CMB in the Standard Model of the Universe (I).
- **Peter BIERMANN** (MPI-Bonn, Germany & Univ of Alabama, Tuscaloosa, USA) Ultra High Energy Particles in the Universe
- **Daniel BOYANOVSKY** (Univ. of Pittsburgh, Dept of Physics and Astronomy, USA) Dark Matter Transfer Function, Free Streaming and Sterile Neutrinos as Dark Matter Candidates
- **James BULLOCK** (Univ. of California, Irvine, USA) Milky Way Satellites: Near Field Cosmology with the Most Dark Matter Dominated Galaxies in the Universe.
- **Asantha COORAY** (Univ. of California, Irvine, USA) Sunyaev-Zeldovich Effect Angular Power Spectrum: Measurements with BOOMERanG & Theoretical Comparisons
- **Claudio DESTRI** (INFN Univ. Milano-Bicocca Dpt. di Fisica, Italy) New Monte Carlo Markov Chain Analysis of CMB + LSS data with the Effective Theory of Inflation and the Early Fast-Roll Stage.
- **Eiichiro KOMATSU** (Univ of Texas, Dept of Astronomy, Austin, USA) How WMAP Helps Constrain the Nature of Dark Energy
- **Anthony N. LASENBY** (Cavendish Laboratory, Cambridge, UK) The CMB in the Standard Model of the Universe: A Status Report
- **Hector J. DE VEGA** (CNRS LPTHE Univ de Paris VI, France) The Effective Theory of Inflation and the Early Fast-Roll Stage, Dark Matter and Dark Energy in the Standard Model of the Universe
- **Carlos S. FRENK** (Institute for Computational Cosmology, Durham, UK) Large and Small Scale Structure in the Standard Model of the Universe
- **Gerard F. GILMORE** (Institute of Astronomy, Cambridge University, UK) Properties of Dark Matter on Small Astrophysical Scale
- **Massimo GIOVANNINI** (INFN Univ. Milano-Bicocca Dpt. di Fisica, Italy) Cosmological Magnetic Fields in the Standard Model of the Universe
- **Reno MANDOLESI** (INFN Univ Padova, Italy) Measurements of the CMB by the PLANCK satellite and their implications
- **Sabino MATARRESE** (INFN Univ Padova, Italy) Primordial Non-Gaussianity and the CMB in the Standard Model of the Universe (II).
- **Rafael REBOLO** (Instituto Astrofisico de Canarias, Tenerife, Spain) CMB Polarization: The QUIJOTE CMB Experiment
- **Norma G. SANCHEZ** (CNRS LERMA Observatoire de Paris, France) Understanding of Inflation and the Early Fast-Roll Stage, Dark Matter and Dark Energy in the Standard Model of the Universe
- **Paul R. SHAPIRO** (Univ of Texas, Dept of Astronomy, Austin, USA) Reionization History of the Universe and the 21cm Background

George SMOOT (LBL, Univ. of California, Berkeley, USA) CMB Observations and the Standard Model of the Universe

... **And Other Lecturers**

PURPOSE AND TOPICS

The Conference is within the astrofundamental physics spirit of the Chalonge School, focalized on recent observational and theoretical progress on the CMB, dark matter, dark energy, dark ages, and the theory of the early universe with predictive power in the context of the Standard Model of the Universe.

In summary, the aim of the meeting is to put together real cosmological data and hard theory predictive approach connected to them in the framework of the Standard Model of th Universe.

An exhibition will retrace the activity of the Chalonge School and George Smoot participation to the School along these 18 years.

All participants are invited to take part in the discussions.

A tour of Perrault building guided by Suzanne DEBARBAT will take place around an exibition of the historical patrimony of Observatoire de Paris.

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http://chalonge.obspm.fr

H. J. DE VEGA N. G. SANCHEZ M. C. FALVELLA

II. PROGRAMME AND LECTURERS

- **Tom ABEL** (Stanford Univ., Physics Dept. CA, USA) First Galaxies and Cosmological Reionization.
- **Nicola BARTOLO** (INFN Univ Padova, Italy) Primordial Non-Gaussianity and the CMB in the Standard Model of the Universe (I.)
- **Peter BIERMANN** (MPI-Bonn, Germany and Univ of Alabama, Tuscaloosa, USA) Ultra High Energy Particles in the Universe
- **Daniel BOYANOVSKY** (Univ. of Pittsburgh, Dept of Physics and Astronomy, USA) Dark Matter Transfer Function, Free Streaming and Sterile Neutrinos as Dark Matter Candidates
- **James BULLOCK** (University of California, Irvine, USA) Milky Way Satellites: Near Field Cosmology with the Most Dark Matter Dominated Galaxies in the Universe.
- **Asantha COORAY** (University of California, Irvine, USA) Cosmology with the 21 cm Background
- **Claudio DESTRI** (INFN Univ. Milano-Bicocca Dpt. di Fisica, Italy) New Monte Carlo Markov Chain Analysis of CMB +LSS data with the Effective Theory of Inflation and the Early Fast-Roll Stage.
- **Hector J. DE VEGA** (CNRS LPTHE Univ de Paris VI, France) The Effective Theory of Inflation and the Early Fast-Roll Stage, Dark Matter and Dark Energy in the Standard Model of the Universe
- **Carlos S. FRENK** (Institute for Computational Cosmology, Durham, UK) The Small-Scale Structure of the Universe
- **Gerard F. GILMORE**, (Institute of Astronomy, Cambridge University, UK) Properties of Dark Matter on Small Astrophysical Scales
- **Massimo GIOVANNINI** (INFN Univ. Milano-Bicocca Dpt. di Fisica, Italy) Cosmological Magnetic Fields in the Standard Model of the Universe
- **Alexander KASHLINSKY** (NASA Goddard Space Flight Center, Greenbelt, MD, USA) Probing large-scale peculiar flows of clusters of galaxies.
- **Eiichiro KOMATSU** (Univ of Texas, Dept of Astronomy, Austin, USA) How WMAP Helps Constrain the Nature of Dark Energy
- **Anthony N. LASENBY** (Cavendish Laboratory, Cambridge, UK) The CMB in the Standard Model of the Universe: A Status Report
- **Reno MANDOLESI** (INAF-IASF Bologna, Italy): Measurements of the CMB by the PLANCK satellite and their Implications
- **Sabino MATARRESE** (INFN Univ Padova, Italy): Primordial Non-Gaussianity and the CMB in the Standard Model of the Universe (II).
- **Rafael REBOLO** (Instituto Astrofisico de Canarias, Tenerife, Spain) CMB Polarization: The QUIJOTE CMB Experiment
- **Paolo SALUCCI** (SISSA-Astrophysics, Trieste, Italy) The Dark Matter Surface Density in Galaxies and Cored Density Profiles
- **Norma G. SANCHEZ** (CNRS LERMA Observatoire de Paris, France) Understanding of Inflation and the Early Fast-Roll Stage, Dark Matter and Dark Energy in the Standard Model of the Universe
- **Paul R. SHAPIRO**, Univ of Texas, Dept of Astronomy, Austin, USA Reionization History of the Universe and the 21cm Background
- **George SMOOT** (LBL, Univ. of California, Berkeley, USA) CMB Observations and the Standard Model of the Universe

III. HIGHLIGHTS BY THE LECTURERS

More informations on the Colloquium Lectures are at:
http://www.chalonge.obspm.fr/colloque2009.html

A. Peter Biermann[1,2,3,4,5]

with Julia Becker[6,7], Laurenţiu Caramete[1,8], Laszlo Á. Gergely[9], Ioana C. Mariş[5], Athina Meli[10], Eun-Suk Seo[11], Vitor de Souza[12], Todor Stanev[13], Oana Taşcău[14]

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[11] IPST and Dept. of Physics, Univ. of Maryland, College Park, MD, USA
[12] Universidade de São Paulo, Instituto de Física de São Carlos, Brazil
[13] Bartol Research Inst., Univ. of Delaware, Newark, DE, USA
[14] Phys. Dept., Univ. Wuppertal, Germany

Ultra High Energy Particles and Cosmic Ray Electrons/Positrons: from Massive Star Explosions

The subtle properties of massive star are shown to be key to understand various new results in cosmic rays, both at low and at extremely high energies.

The recent discovery of an excess cosmic ray electron and positron component is naturally explained in the context of recognizing, that stars with magnetic winds have a well-known topology in their wind:

This means (1993) that the cosmic rays resulting from the explosion of such stars have a small polar cap component with E^{-2}, and for most of their surface give a spectrum of $E^{-7/3}$. This explains readily (2009) the new results from Pamela, ATIC, Fermi and H.E.S.S., using the model predicted in 1993.

Ultra high energy cosmic rays may be heavy nuclei, and then the question is from what source: The radio galaxy Cen A is nearby, and has a decaying star-burst, when very many massive stars were formed, which have recently exploded. The relativistic shock in the jet in Cen A can only contain heavy nuclei at very high energies.
In such a case, the spectrum of the various heavy elements from the polar cap component can be boosted up in energy by $\Gamma_{sh}^2 = 2500$, possibly explaining the spectrum of these high energy particles and their chemical composition. Many more predictions follow from such a scheme, which therefore can easily be disproven, or supported.

PARTICLES AS TRACERS FOR THE MOST MASSIVE EXPLOSIONS IN THE MILKY WAY

At their deaths, the most massive stars in the Milky Way seem to leave behind unambiguous signatures of particles. Recently, a population of electrons and positrons was observed by several experiments. Attempts were made to attribute such a signal to the decay of dark matter. However, a natural explanation is in the explosions of giant stars that are more than 15 times heavier than our sun.

A dying star of very high mass ejects most of its matter in a final explosion, which then ploughs its way through a massive stellar wind. During this process, electrons and positrons escape from two different regions: the lower energy signal comes from the entire surface of the exploding star, while at higher energies, the regions around the poles of the rotating star start to dominate. This naturally explains the observed energy behavior of electrons and positrons.

References:

"'Cosmic ray electrons and positrons from supernova explosions of massive stars"', P.L. Biermann, J.K. Becker, A. Meli, W. Rhode, E.-S. Seo and T. Stanev
Phys.Rev.Lett.103:061101,2009, arXiv:0903.4048 Categories: astro-ph.HE astro-ph.GA

B. James Bullock

Center for Cosmology, University of California, Irvine, USA.

Dark Matter and Dwarf Galaxies: Evidence for a threshold mass in galaxy formation?

- We have derived a new and accurate mass-estimator for dispersion supported galaxies that is correct for general assumptions about stellar velocity anisotropy and dark matter vs. stellar content. Specifically the mass within the $3-d$ half-light radius $r_{1/2}$ of a stellar system is given by the following simple, yet accurate formula: $M(r_1/2) = 3G^{-1}r_{1/2}\sigma^2_{los}$, where σ_{los} is the luminosity-weighted line-of-sight velocity dispersion.
  Reference: Wolf et al. (2009, to be submitted)

- All of the dwarf satellite galaxies of the Milky Way are consistent with inhabiting a halo of a common mass, M_{vir} 10^9Msun. Remarkably, the least luminous dwarfs, with luminosities as low as $300L_{sun}$ seem to inhabit dark matter halos that are just as massive as those of their more luminous counterparts, which are $10,000$ times brighter. The lack of observed trend between central dark matter density and luminosity is difficult to explain with current models and may be indicative of a low-mass threshold in galaxy formation.
  Reference: Strigari et al. (2008, Nature)

- We have used completeness limits from the SDSS to argue that there is likely a very large population of undiscovered, low-luminosity dwarf galaxies orbiting within the halo of the Milky Way. Straightforward corrections indicate that there are approximately 500 galaxies with luminosities greater than $1000L_{sun}$ within $400kpc$ of the Sun. Future surveys like LSST can detect these galaxies. Whether they are discovered or not, these searches will provide important constraints on the nature of dark matter and on models of galaxy formation.
  Reference: Tollerud et al. (2008, ApJ)

- Dwarf satellite galaxies provide ideal astrophysical sources for dark matter indirect detection experiments because they have high dark matter densities, neglibigle astrophysical backgrounds, and are fairly nearby. Sculptor and Segue 1 are the most promising candidates for Fermi and ACTs.
  Reference: Strigari et al. (2008, ApJ) + Martinez et al. (2009, JCAP)

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H.J.dV: LPTHE, CNRS/Université Paris VI-P. & M. Curie & Observatoire de Paris, Paris, France
N.G.S: LERMA, CNRS/Observatoire de Paris, Paris, France

The Effective Theory of Inflation in the Standard Model of the Universe and the CMB+LSS data analysis

Inflation is today a part of the Standard Model of the Universe supported by the cosmic microwave background (CMB) and large scale structure (LSS) datasets.

Inflation solves the horizon and flatness problems and naturally generates density fluctuations that seed LSS and CMB anisotropies, and tensor perturbations (primordial gravitational waves).

Inflation theory is based on a scalar field φ (the inflaton) whose potential is fairly flat leading to a slow-roll evolution.

This review focuses on the following new aspects of inflation. We present the effective theory of inflation à la **Ginsburg-Landau** in which the inflaton potential is a polynomial in the field φ and has the universal form $V(\varphi) = N\ M^4\ w(\varphi/[\sqrt{N}\ M_{Pl}])$, where $w = \mathcal{O}(1),\ M \ll M_{Pl}$ is the scale of inflation and $N \sim 60$ is the number of efolds since the cosmologically relevant modes exit the horizon till inflation ends.

The slow-roll expansion becomes a systematic $1/N$ expansion and the inflaton couplings become **naturally small** as powers of the ratio $(M/M_{Pl})^2$. The spectral index and the ratio of tensor/scalar fluctuations are $n_s - 1 = \mathcal{O}(1/N),\ r = \mathcal{O}(1/N)$ while the running index turns to be $dn_s/d\ln k = \mathcal{O}(1/N^2)$ and therefore can be neglected. The **energy scale of inflation** $M \sim 0.7 \times 10^{16}$ GeV is completely determined by the amplitude of the scalar adiabatic fluctuations.

A complete analytic study plus the Monte Carlo Markov Chains (MCMC) analysis of the available CMB+LSS data (including WMAP5) with fourth degree trinomial potentials showed:

- **(a)** the **spontaneous breaking** of the $\varphi \to -\varphi$ symmetry of the inflaton potential.

- **(b)** a **lower bound** for r in new inflation: $r > 0.023$ (95% CL) and $r > 0.046$ (68% CL).

- **(c)** The preferred inflation potential is a **double well**, even function of the field with a moderate quartic coupling yielding as most probable values: $n_s \simeq 0.964,\ r \simeq 0.051$. This value for r is within reach of forthcoming CMB observations.

- **(d)** The present data in the effective theory of inflation clearly **prefer new inflation**.

- **(e)** Study of higher degree inflaton potentials show that terms of degree higher than four do not affect the fit in a significant way. In addition, horizon exit happens for $\varphi/[\sqrt{N}\ M_{Pl}] \sim 0.9$ making higher order terms in the potential w negligible.

We summarize the physical effects of **generic** initial conditions (different from Bunch-Davies) on the scalar and tensor perturbations during slow-roll and introduce the transfer function $D(k)$ which encodes the observable initial conditions effects on the power spectra. These effects are more prominent in the *low* CMB multipoles: a change in the initial conditions during slow roll can account for the observed CMB **quadrupole suppression**.

Slow-roll inflation is generically preceded by a short **fast-roll** stage. Bunch-Davies initial conditions are the natural initial conditions for the fast-roll perturbations. During fast-roll, the potential in the wave equations of curvature and tensor perturbations is purely attractive and leads to a suppression of the curvature and tensor CMB quadrupoles.

A MCMC analysis of the WMAP+SDSS data **including fast-roll** shows that the quadrupole mode exits the horizon about 0.2 efold before fast-roll ends and its amplitude gets suppressed. In addition, fast-roll fixes the **initial inflation redshift** to be $z_{init} = 0.9 \times 10^{56}$ and the **total number** of efolds of inflation to be $N_{tot} \simeq 64$.

Fast-roll fits the TT, the TE and the EE modes well reproducing the quadrupole supression.

A thorough study of the **quantum loop corrections** reveals that they are very small and controlled by powers of $(H/M_{Pl})^2 \sim 10^{-9}$, **a conclusion that validates the reliability of the effective theory of inflation.**

The present review shows how powerful is the Ginsburg-Landau effective theory of inflation in predicting observables that are being or will soon be contrasted to observations.

References, Review article:

D. Boyanovsky, C. Destri, H. J. de Vega, N. G. Sanchez,

arXiv:0901.0549, Int. J. Mod. Phys. A24, 3669-3864 (2009)

and author's references therein.

D. H.J. de Vega, N.G. Sanchez

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Dark Matter at the keV scale from Theory and Observations

The nature of Dark Matter (DM) is unknown. It is a forefront problem of modern cosmology. Only the gravitational effects of DM are observed and they are necessary to explain the present structure of the Universe in the context of the standard Cosmological model. DM particles must be neutral and so weakly interacting that no effects are so far detectable. There are extremely many DM particle candidates beyond the standard Model of particle physics.

A new analysis of the dark matter particle mass, taking into account theory, galaxy observations and numerical simulations indicates that the mass of the dark matter particle is in the keV scale (keV = 1/511 electron mass) and the temperature when the dark matter decoupled from ordinary matter and radiation would be $100 GeV$ at least. [1-4].

This analysis is based on the generic properties of the distribution function and the phase density of dark matter particles, **independent of the particle physics model**. The several generic possibilities for the dark matter particles have been considered: at decoupling they could be ultra-relativistic or non-relativistic, at or out local thermal equilibrium. In all cases, the dark matter particles are "cold" enough to allow galaxy formation, their mass turns to be at the keV scale and the dark matter interactions (other than gravity) are negligible.

[So far, the search for dark matter particles concentrated unsuccessfully on much heavier particles with masses of 10 GeV or more].

Two independent constraints are used: The known cosmological DM density today $\rho_{DM}(\text{today}) = 1.107 \ \frac{\text{keV}}{\text{cm}^3}$, and the phase-space density $Q = \rho/\sigma^3$ which is invariant under the cosmological expansion and can only decrease under self-gravity interactions (gravitational clustering). The value of Q today follows from galaxy observations : $Q_{today} = (0.18 \text{ keV})^4$. We compute explicitly Q_{prim} (in the primordial universe) and it turns to be proportional to m^4 [1-4].

Alternatively, we use the surface acceleration of gravity in DM dominated galaxies and thus provide two quantitative ways to derive the value of m and the decoupling temperature T_d in refs. [1-4]. The dark matter particle mass m and decoupling temperature T_d are **mildly** affected by the uncertainty in the factor Z through a power factor 1/4 of this uncertainty, namely, by a factor $10^{\frac14} \simeq 1.8$

No assumption about the nature of the dark matter particle is made. The keV range DM particle mass is much larger than the temperature during the matter dominated era (which is less than 1 eV), hence the keV dark matter is **cold** (CDM).

The comoving Jeans' (free-streaming) wavelength, ie the largest wavevector exhibiting gravitational instability (Fig. 1), and the Jeans' mass (the smallest unstable mass by gravitational collapse) are obtained in the range

$$\frac{0.76}{\sqrt{1+z}} \text{ kpc} < \lambda_{fs}(z) < \frac{16.3}{\sqrt{1+z}} \text{ kpc} \ , \ 0.45 \ 10^3 \ M_\odot < \frac{M_J(z)}{(1+z)^{+\frac32}} < 0.45 \ 10^7 \ \ M_\odot \ .$$

These values at $z = 0$ are consistent with the N-body simulations and are of the order of the small dark matter structures observed today . By the beginning of the matter dominated era $z \sim 3200$, the masses are of the order of galactic masses $\sim 10^{12} \ M_\odot$ and the comoving free-streaming wavelength scale turns to be of the order of the galaxy sizes today ~ 100 kpc ,.

Lower and upper bounds for the dark matter annihilation cross-section σ_0 are derived: $\sigma_0 > (0.239 - 0.956) \ 10^{-9} \ \text{GeV}^{-2}$ and $\sigma_0 < 3200 \ m \ \text{GeV}^{-3}$. There is at least five orders of magnitude between them , the dark matter non-gravitational self-interaction is therefore negligible (consistent with structure formation and observations, as well as by comparing X-ray, optical and lensing observations of the merging of galaxy clusters with N-body simulations).

Typical "wimps" (weakly interacting massive particles) with mass $m = 100$ GeV and $T_d = 5$ GeV would require a huge $Z \sim 10^{23}$, well above the upper bounds obtained and cannot reproduce the observed galaxy properties. They produce an extremely short free-streaming or Jeans length λ_{fs} today $\lambda_{fs}(0) \sim 3.51\ 10^{-4}$ pc $= 72.4$ AU that would correspond to unobserved structures much smaller than the galaxy structure. Wimps result strongly disfavoured.

References

[**1**] H. J. de Vega, N. G. Sanchez, arXiv:0901.0922, Mon. Not. R. Astron. Soc. 404, 885 (2010).

[**2**] D. Boyanovsky, H. J. de Vega, N. G. Sanchez, arXiv:0710.5180, Phys. Rev. D77, 043518 (2008)

[**3**] H. J. de Vega, N. G. Sanchez, arXiv:0907.0006.

[**4**] D. Boyanovsky, H. J. de Vega, N. G. Sanchez, arXiv:0807.0622, Phys. Rev. D78, 063546 (2008).

E. Massimo Giovannini

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INFN, Section of Milan-Bicocca, 20126 Milan, Italy

Large-scale magnetic fields in the standard model

For reasons of space, only some of the results obtained during 2009 have been reported in this talk. Relevant references are:

- (1) M. Giovannini, Phys. Rev. D79, 121302 (2009).
- (2) M. Giovannini, Phys. Rev. D79, 103007 (2009).
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The parameters of a putative magnetized background have been estimated, for the first time, from the observed temperature autocorrelation (TT angular power spectra) as well as from the measured temperature-polarization cross correlation (TE angular power spectra) (see (1)-(2)).

Likelihood contours have been presented (see (1)-(2)). The dependence of the temperature and polarization angular power spectra upon the parameters of an ambient magnetic field can be encoded in the scaling properties of a set of basic integrals whose derivation is simplified in the limit of small angular scales.

The magnetically-induced distortions patterns of the relevant observables can be computed analytically by employing scaling considerations which are corroborated by numerical results. The parameter space of the magnetized cosmic microwave background anisotropies is also discussed in the light of the obtained analytical results (see (2)-(3)). The propagation of electromagnetic disturbances in a magnetized plasma leads naturally to a B-mode polarization whose angular power spectrum can be computed both analytically and numerically (4).

A strategy for the direct extraction of the magnetized B-mode autocorrelations from the forthcoming experimental data has been presented and discussed. Taken at face value, the results presented here and reported in the aforementioned publications, illustrate, for the first time, how the parameters of a magnetized background can be systematically included and estimated in the LambdaCDM paradigm as well as in its neighboring extensions (5).

The research program illustrated in this talk has been formulated through various steps and the references quoted in (1)-(5) can be usefully consulted.

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Large-scale peculiar flows of clusters of galaxies

In the standard cosmological paradigm, large-scale peculiar velocities arise from gravitational instability due to mass inhomogeneities seeded during inflationary expansion. On sufficiently large scales, ¿ 100 Mpc, this leads to a robust prediction of the amplitude and coherence length of these velocities.

For clusters of galaxies, their peculiar velocities can be measured from the kinematic component of the Sunyaev-Zeldovich (SZ) effect produced by the Compton scattering of cosmic microwave background (CMB) photons off the hot intracluster gas. This talk discusses results from measurements of the large scale peculiar flows using a large X-ray cluster catalog and all sky CMB maps from the WMAP satellite (Kashlinsky et al 2008, ApJ, 686, L49 and 2009, 691, 1479).

The analysis utilizes the method proposed by us earlier (Kashlinsky and Atrio-Barandela 2000, ApJ, 536, L67): it computes the dipole in the cosmic microwave (CMB) data at cluster pixels, which preserves the KSZ component, while integrating down other contributions.

In a parallel study we demonstrated that the hot gas in clusters is well described by the Navarro-Frenk-White density profile (Atrio-Barandela et al 2008, 675, L57). Such NFW clusters have gas temperature decrease toward outer parts consistent with the available X-ray measurements, so the thermal SZ integrates down with increasing cluster aperture enabling to isolate the KSZ component in the dipole.

The discussion addresses in great detail the possible systematics that can confuse our measurements and it is demonstrated that - given the quality of the cluster catalog - the various systematic effects are small and cannot reproduce the measured dipole.

G. Eiichiro Komatsu

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How WMAP Helps Constrain the Nature of Dark Energy

I presented a method to compress the information on the nature of dark energy, contained in the cosmic microwave background (CMB) data obtained by the WMAP satellite, to just three numbers, and showed the latest limits on time evolution of dark energy density using the distance information (angular diameter distances from CMB and the distribution of galaxies, as well as luminosity distances from Type Ia supernovae) alone.

The current limits are fully consistent with dark energy being a cosmological constant, with the present-day equation of state parameter constrained as $w = -1.00 \pm 0.19$ (68%CL).

I then presented a way to improve on this limit significantly, by including the full power spectrum information contained in the distribution of galaxies.

As an example I presented how the Hobby-Eberly Dark Energy Experiment (HETDEX), which is a large redshift survey developed by the University of Texas and the partner institutions, can determine the important quantities for constraining the nature of dark energy - the angular diameter distances and Hubble expansion rates - with much better (more than a factor of two) accuracy compared with a now- popular method that uses only the Baryon Acoustic Oscillations. The HETDEX survey is scheduled to begin in 2011.

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CMB Observations: Current Status and Implications for Theory

The Cosmic Microwave Background (CMB), is a wonderful tool in modern cosmology. A significant fraction of all the information in cosmology over the last 10 to 15 years has come from it, and it has finally ushered us into an era of 'precision cosmology' (the latter, of course, accompanied by deep mysteries as to the nature of the quantities, such as 'dark energy' and 'dark matter', which we are measuring so accurately).

The aim of the talk was to give an overview of the current state of CMB observations and their scientific implications.

One of the big questions that current and forthcoming CMB observations can help with, is the dynamics and energy scale of inflation. A key observation in this respect would be detection of B-mode CMB polarization, which would enable us to determine the parameter r, the ratio of tensor to scalar modes of primordial perturbations. In this respect, some new interesting polarization results are coming out from two current experiments.

Recent results from the QUAD experiment at the South Pole ([1]) show that the expected peak structure in the E-mode at scales between about 200 to 2000 in l has been definitely detected, at high significance.

Recent results from BICEP (also at the South Pole), give a direct limit to the B mode level of $r < 0.73$ at 95% confidence ([2]). This is much larger than the limit of $r < 0.22$ at 95% given by [4]. However, the latter is not a direct limit, but comes via a combination of constraints from T and E mode CMB (principally from the 5 year WMAP observations), together with large scale structure data and supernovae. Chiang et al. [2] show that the direct upper limit on B-modes from current WMAP data is $r < 6$.

The next two years should see a very considerable improvement in CMB measurements on all scales with data starting to come through from the Planck satellite, which was successfully launched on May 14th 2009. Detection of an r value as low as 0.05 should be possible with a Planck mission that includes 4 sky coverages (see [3]), as well as a much improved measurement of the slope of the primordial scalar spectrum, n_s .

Also vitally important for discriminating between competing theories of inflation, are $n - run$ (i.e. is the slope of the primordial spectrum fixed, or does it change with wavenumber), and the question of whether the primordial fluctuations are Gaussian. It is now clear that estimators like $f_n l$ are very good discriminators of the type of inflation, and Planck should give at least a fourfold improvement in accuracy of measurement for this quantity.

Similar advances are also being made for secondary anisotropies. The first 'blank field' Sunyaev-Zeldovich detections have appeared from the South Pole Telescope [6], and the talk included images from the AMI telescope in Cambridge ([7]) which is now well into its first deep blank-field survey.

Other areas in which the CMB can provide crucial information include topics in 'fundamental physics', such as possible constraints (via string cosmology) on the nature of quantum gravity, the detection of topological defects, and the question of whether the universe may have been non-isotropic when the perturbations on largest scales were being laid down. For more on these and related topics see [5].

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IV. SUMMARY AND CONCLUSIONS OF THE COLLOQUIUM BY H.J. DE VEGA, M.C. FALVELLA AND N.G. SANCHEZ

About one hundred participants (from Europe, North and South America, Japan, Russia, Armenia, Latvia, India, Korea, Taiwan, New Zealand, South Africa) attended the Colloquium.

All the announced 19 Lecturers were present, including 4 Daniel Chalonge Medals, among them George Smoot, Nobel prize of Physics. News from WMAP and from Planck were directly reported. Journalists and representatives of the directorate of the Italian Space Agency were present.

Discussions and lectures were outstanding. Inflection points in several current research lines emerged. New important issues and conclusions arised and between them, it worths to highlight:

- **(1)** The primordial CMB fluctuations are almost gaussian, large primordial non-gaussianity and large primordial running index are strongly disfavored. The amount of primordial gravitons r is predicted to be larger than 0.021 and smaller than 0.053, which is at reach of the next CMB observations.

- **(2)** The dark matter particle candidates with high mass (100 GeV, the so called "Wimps") became strongly disfavored, while cored (non cusped) dark matter halos and light (keV scale mass) dark matter are being increasingly favoured from theory and astrophysical observations.

- **(3)** Dark energy observations are pretty consistent with the cosmological constant. CMB + BAO is the winner for measuring spatial curvature, but other standard rulers are to be considered beyond BAO as the horizon size at the matter-radiation equality era, z 3200. The HETDEX survey is expected to determine important quanties for constraining dark energy -as the angular diameter distances and Hubble expansion rates - with much better (more than a factor of two) accuracy compared with methods using only BAO. HETDEX is scheduled to begin in 2011.

- **(4)** The features of electrons and positrons observed recently by Auger, Pamela and HESS are all explained as having their origin in the explosions and winds of massive stars in the Milky Way.

- **(5)** The QUAD experiment at the South Pole shows that the expected peak structure in the E-mode CMB polarization at scales between about 200 to 2000 in l has been definitely detected at high significance. Detection of an r value as low as 0.05 should be possible with a Planck mission that includes 4 sky coverages, as well as a much improved measurement of the scalar primordial index, ns. The first sky strips (first light survey) observed by Planck launched 14th may were presented in avant prmire.

- **(6)** Advances are also being made for CMB secondary anisotropies.The first 'blank field' Sunyaev-Zeldovich detections have appeared from the South Pole Telescope, and new images were presented from the AMI telescope in Cambridge which is now well into its first deep blank-field survey.

Best congratulations and aknowledgements to all lectures and participants which made the 13th Paris Cosmology Colloquium so fruitful and interesting, the Ecole d'Astrophysique Daniel Chalonge looks forward for you for the next Colloquium of this series.

V. AWARD OF THE DANIEL CHALONGE MEDAL 2009

The International School of Astrophysics "Daniel Chalonge" has awarded the Daniel Chalonge Medal 2009 to **Professor Peter Biermann** from the MPI for Radioastronomie of Bonn (D) and University of Alabama-Tuscaloosa (USA).

The medal was awarded to Peter Biermann for his pioneering, impressive and multiple contributions to astrophysics (as for example high energy particle acceleration, cosmic rays, galactic nuclei and black holes), and for his support and outstanding contributions to the Chalonge School. In particular, Peter Biermann is involved in astrophysical dark matter research in the standard model of the universe, one of the most discussed topics in the Chalonge School. Peter Biermann takes part in the programs and life of the School, promoting fruitful discussions and work with the participants and supporting the origin and development of new ideas and projects.

The Chalonge medal was presented to Peter Biermann on July 25, 2009 during the sessions of the 13th Paris Cosmology Colloquium 2009 at the Observatoire de Paris HQ (historic Perrault building) in the Cassini Hall, on the meridian of Paris, which was attended by about hundred participants from the world over, among them three Chalonge Medals.

The Chalonge Medal, coined exclusively for the Chalonge School by the prestigious Hotel de la Monnaie de Paris (the French Mint), is a totally surprise award and only seven Chalonge medals have been awarded in the 18 year school history.

The Medal aknowledges science with great intellectual endeavour and a human face. True and healthy science. Outstanding gentleperson scientists. Scientists recipients of the Daniel Chalonge Medal are Ambassadors of the School.

The list of the awarded Chalonge Medals is the following:

- 1991: Subramanyan Chandrasekhar, Nobel prize of physics.
- 1992: Bruno Pontecorvo.
- 2006: George Smoot, Nobel prize of physics.
- 2007: Carlos Frenk
- 2008: Anthony Lasenby
- 2008: Bernard Sadoulet.
- 2009: Peter Biermann.

The announcement, full history, photo gallery and links are available on line at:

http://chalonge.obspm.fr , click on 'The Daniel Chalonge Medal 2009'

http://chalonge.obspm.fr/Medal_Chalonge2009.pdf

PHOTOS OF THE COLLOQUIUM

are available at 'Album photos':

http://chalonge.obspm.fr/colloque2009.html

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